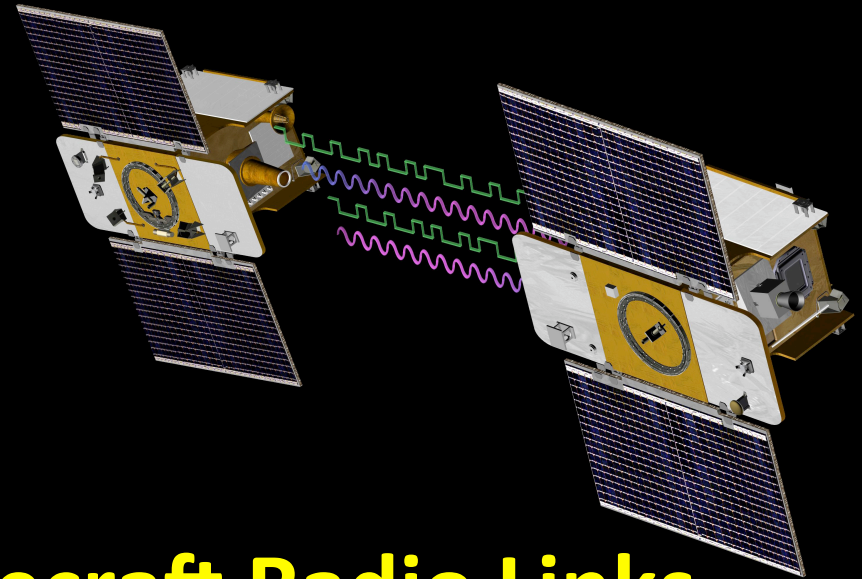


Jet Propulsion Laboratory
California Institute of Technology

8th International Planetary Probe Workshop

6-10 June 2011, Portsmouth, Virginia



Spacecraft-to-Spacecraft Radio Links

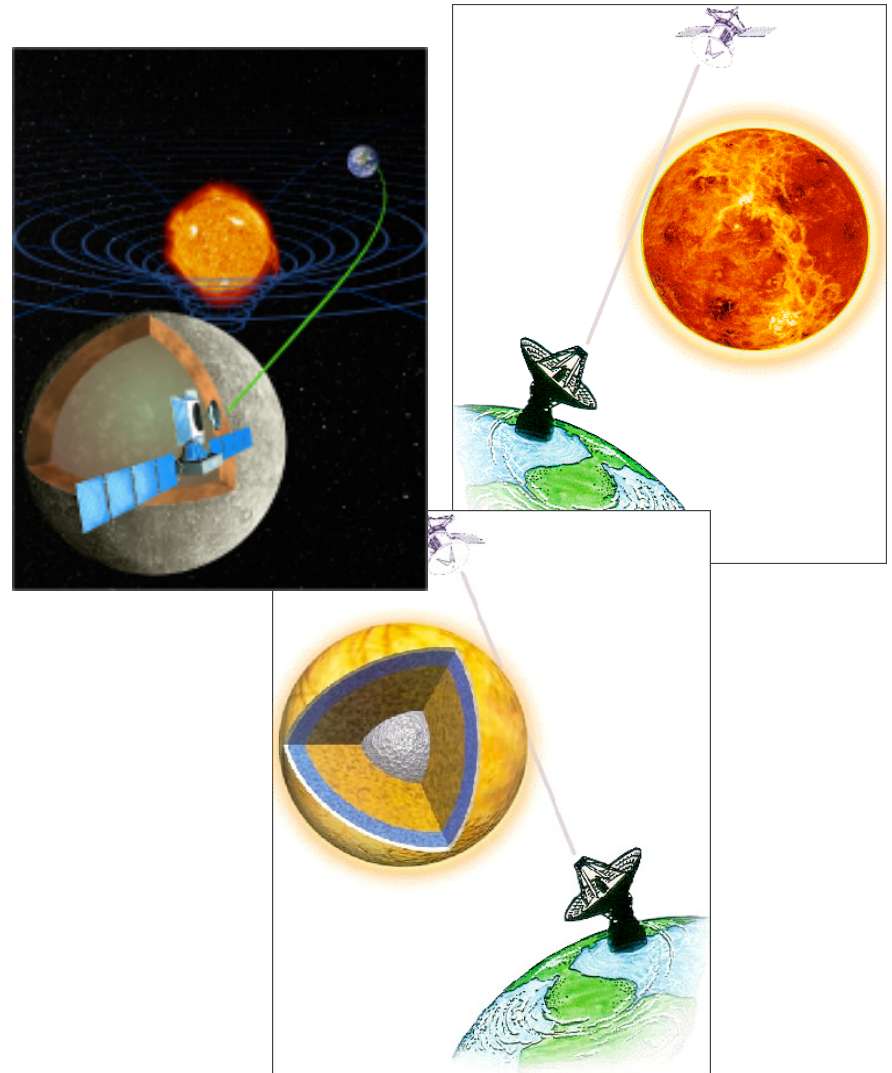
Instrumentation for Planetary Gravity, Atmospheric and Surface Sciences

Sami Asmar

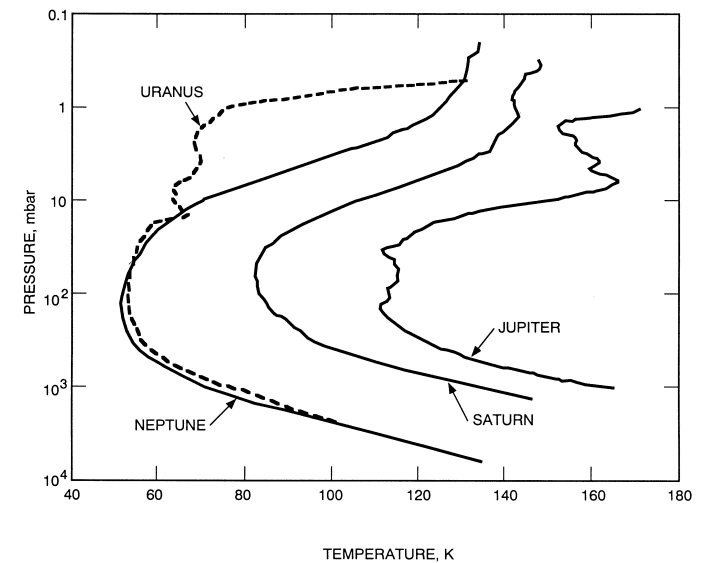
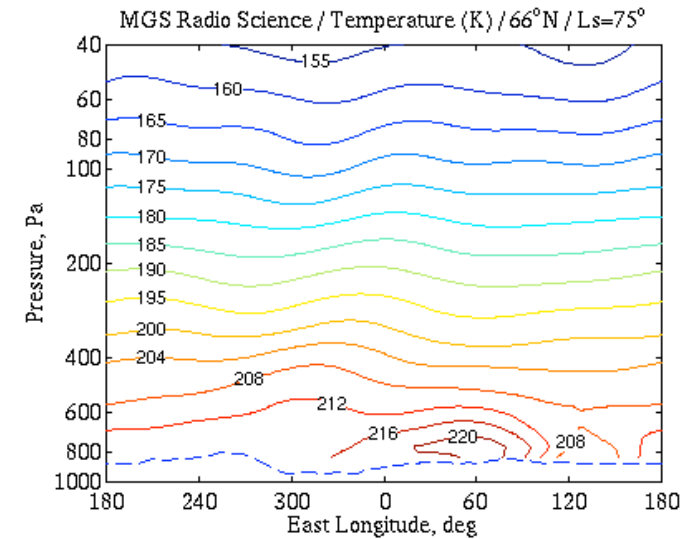
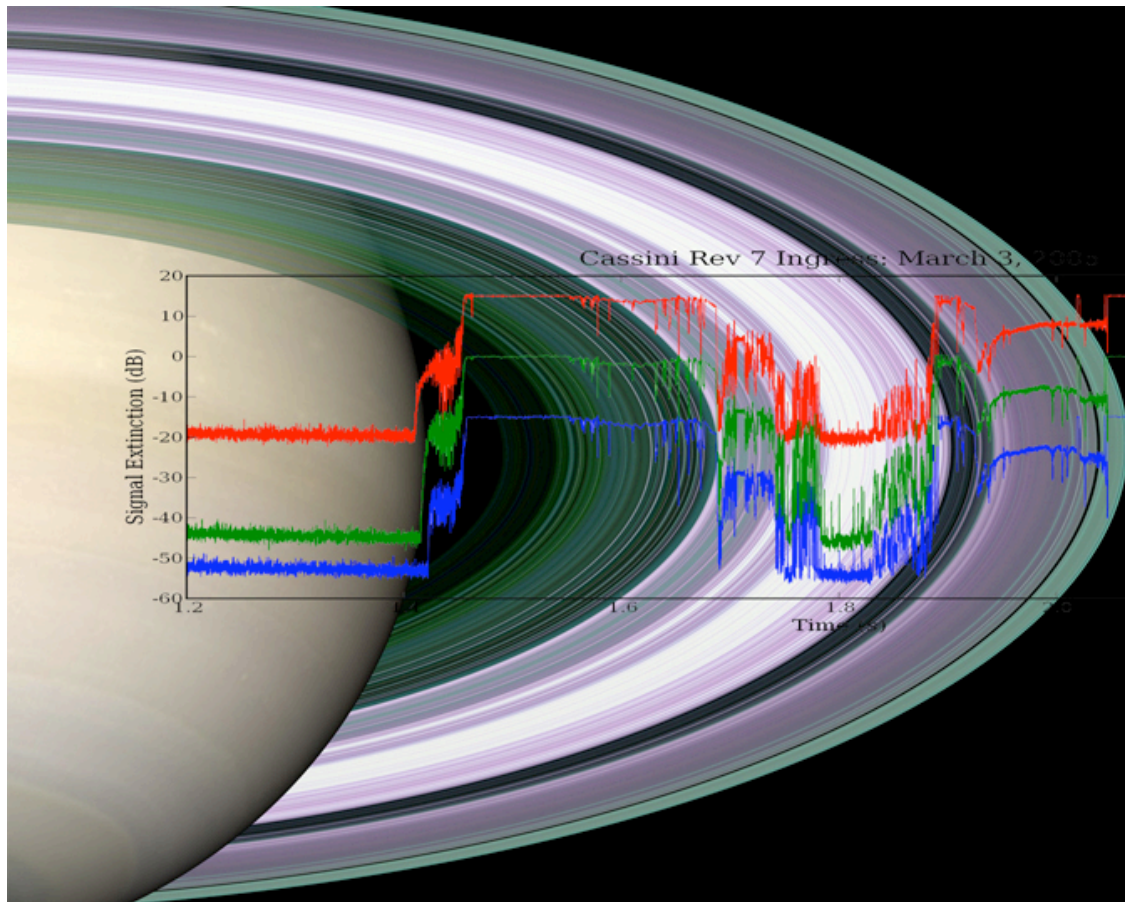
Jet Propulsion Laboratory, California Institute of Technology, Pasadena CA

Motivation

- Traditional Radio Science: links between spacecraft & ground
 - Successful in fields of ring & atmospheric occultations, gravity & interior structure, tests of theories of relativity, solar science, etc.
- Limitations on SNR & geometry
 - Especially for one-way downlink
- New configuration & instrument
- ***Spacecraft-to-spacecraft*** links
 - Significant SNR advantage
 - Improved geometrical coverage
 - Eliminate calibration of Earth atmosphere



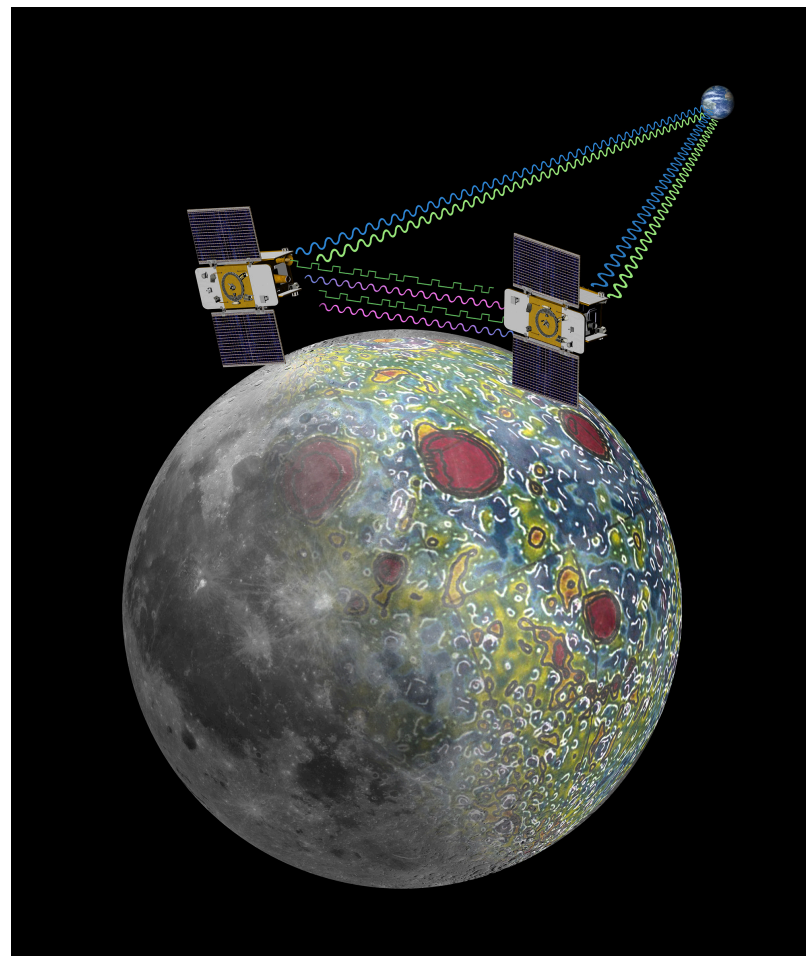
Classic Results of Radio Occultations



Temperature profiles for the giant planets derived from radio occultation data acquired with the Voyager spacecraft (from Lindal, 1992)

S/C-S/C Science Links to Date

- Galileo Probe to Galileo Orbiter DWE
 - Enhanced by link to Earth
- Huygens DWE
 - *Enhanced* by link to Earth
- GRACE Earth Gravity
 - Formation Flying
- GRAIL Lunar Gravity
 - Formation Flying
- SELENE Lunar Farside Gravity
 - Four-way Doppler
- Demonstration with Mars Orbiters
 - UHF between ODY & MRO
- Accidental Possible DWE
 - Phoenix EDL, lander to 3 orbiters

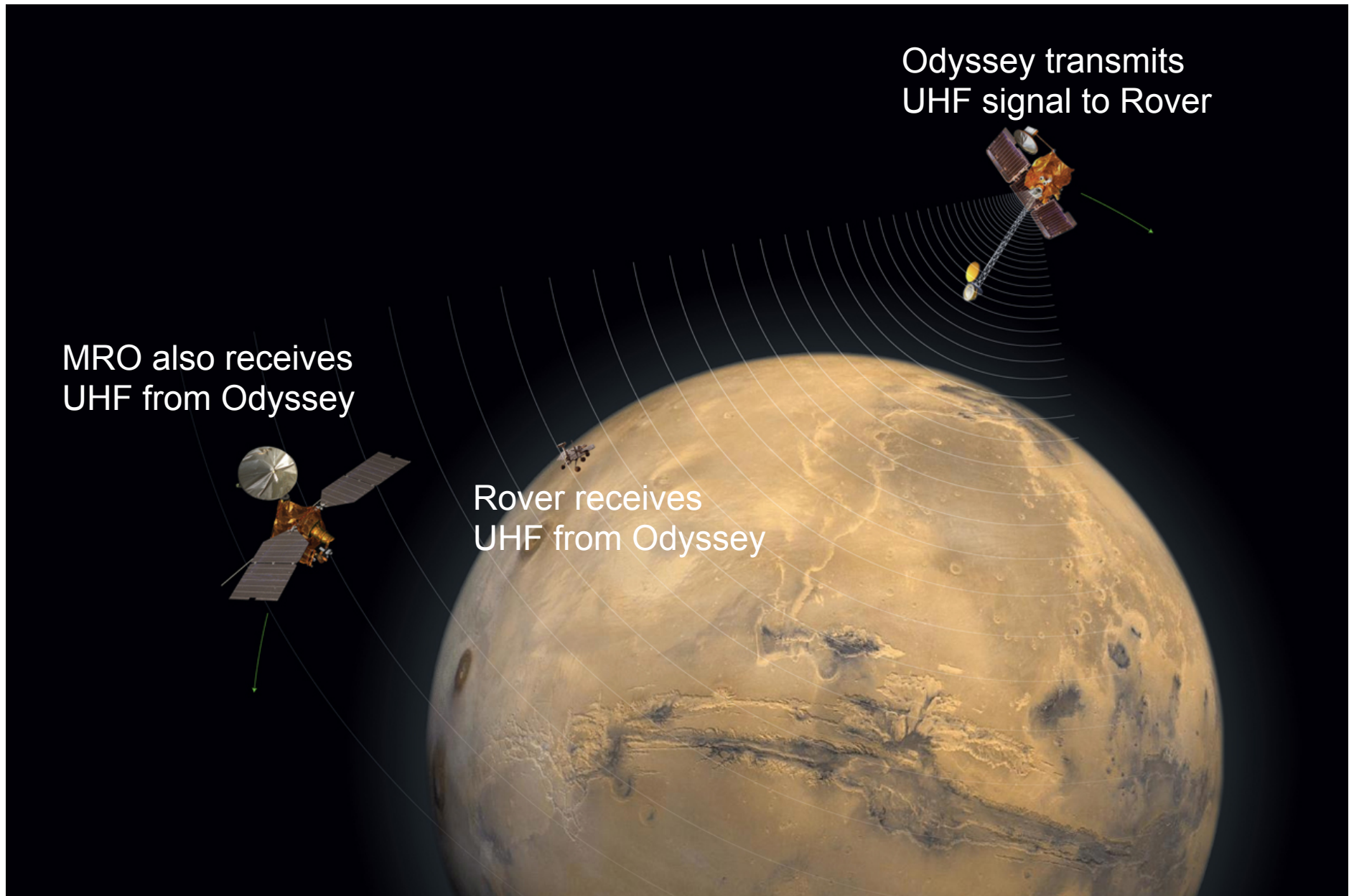


Open-Loop Receiver Miniaturization

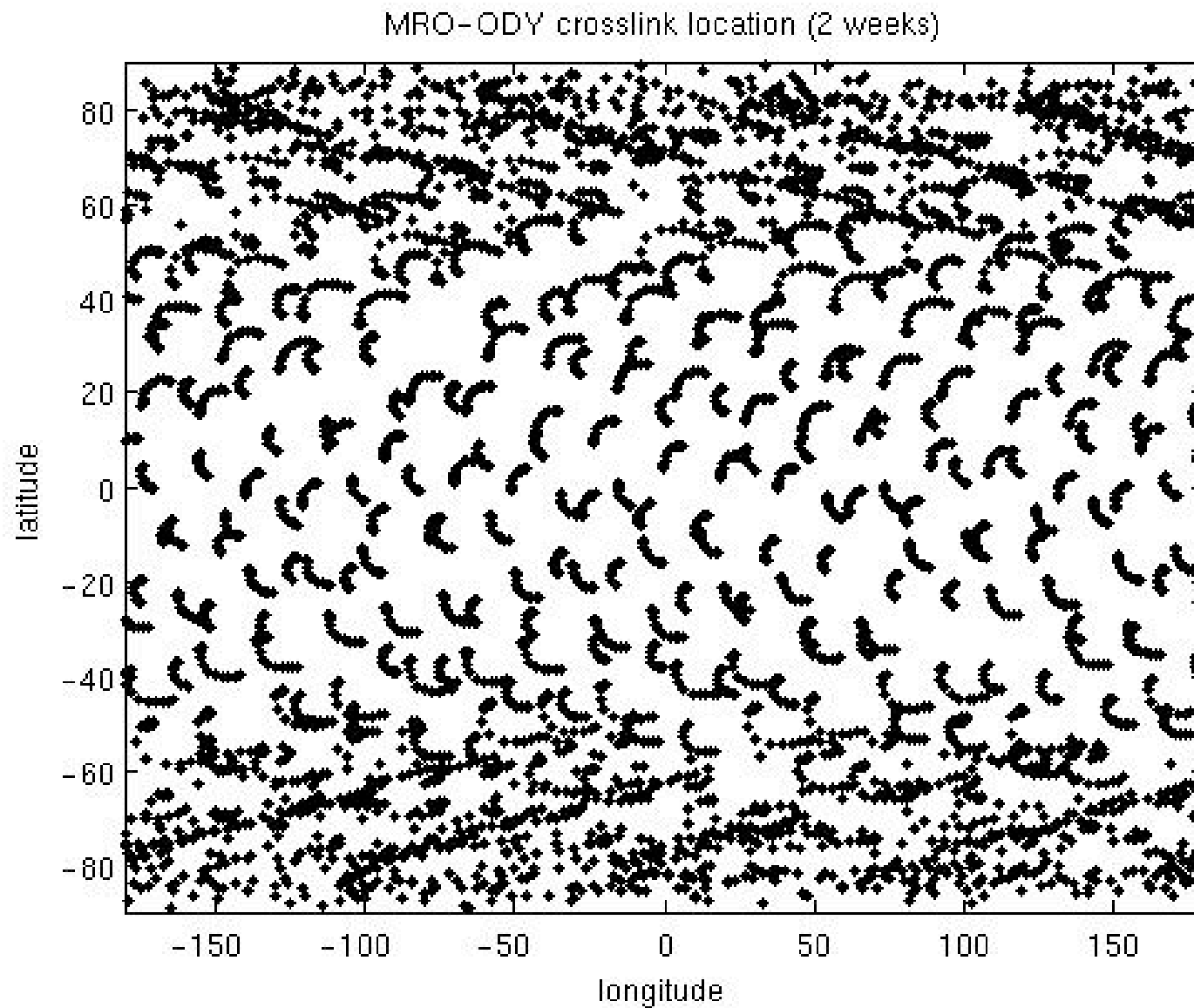
- DSN Open-Loop Radio Science Receiver (RSR) in use for decades
 - Key to proper data acquisition
- RSR Too big to fly
- **Breakthrough:** Software radios for spacecraft transponders
- Prototype (Electra) onboard MRO used to demonstrate spacecraft-to-spacecraft radio science experiments with the Odyssey spacecraft
- New Horizons RSR for uplink occultation
- GRACE & GRAIL another receiver type for precision gravity measurements



Completed Demo of Mars Orbiters Crosslink

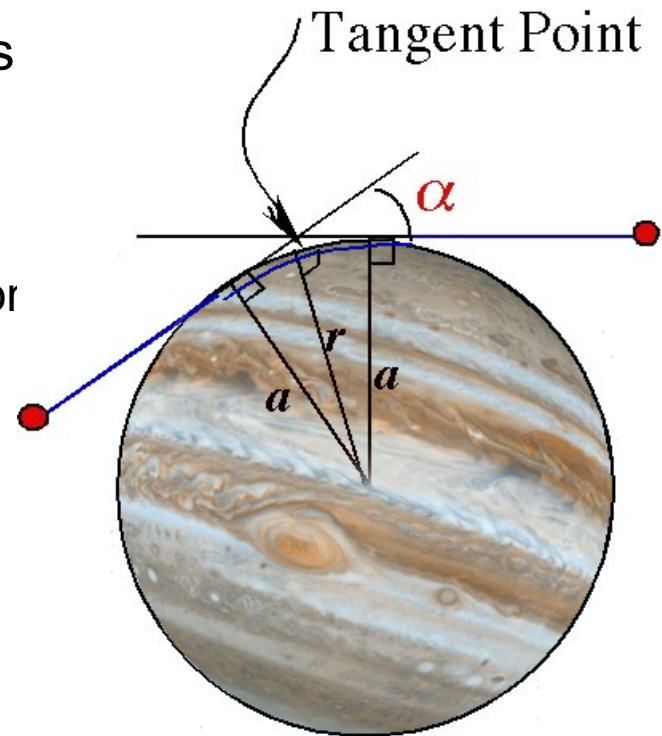


Example of global geometrical coverage



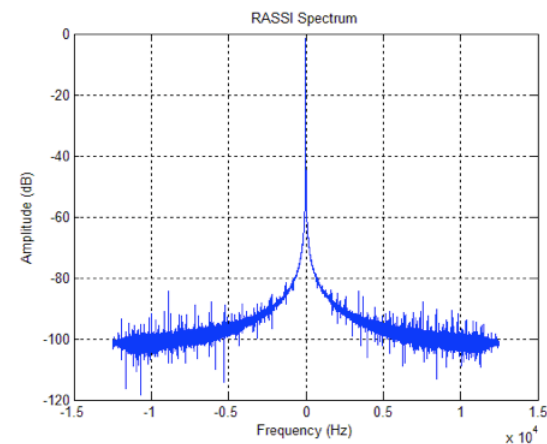
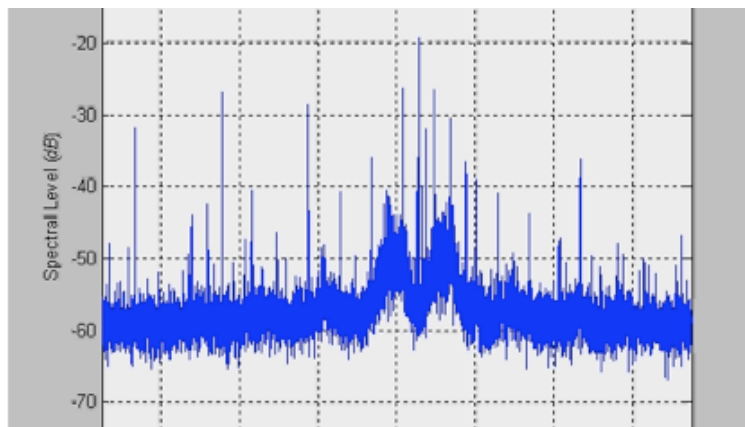
Science

- Scenario of two Jovian system orbiters
- Appropriate wavelengths of the radio links drives the front-end down-converters and the required antennas
 - Longer wavelength to minimize attenuation from NH_3 but susceptible
 - Shorter wavelength less noisy

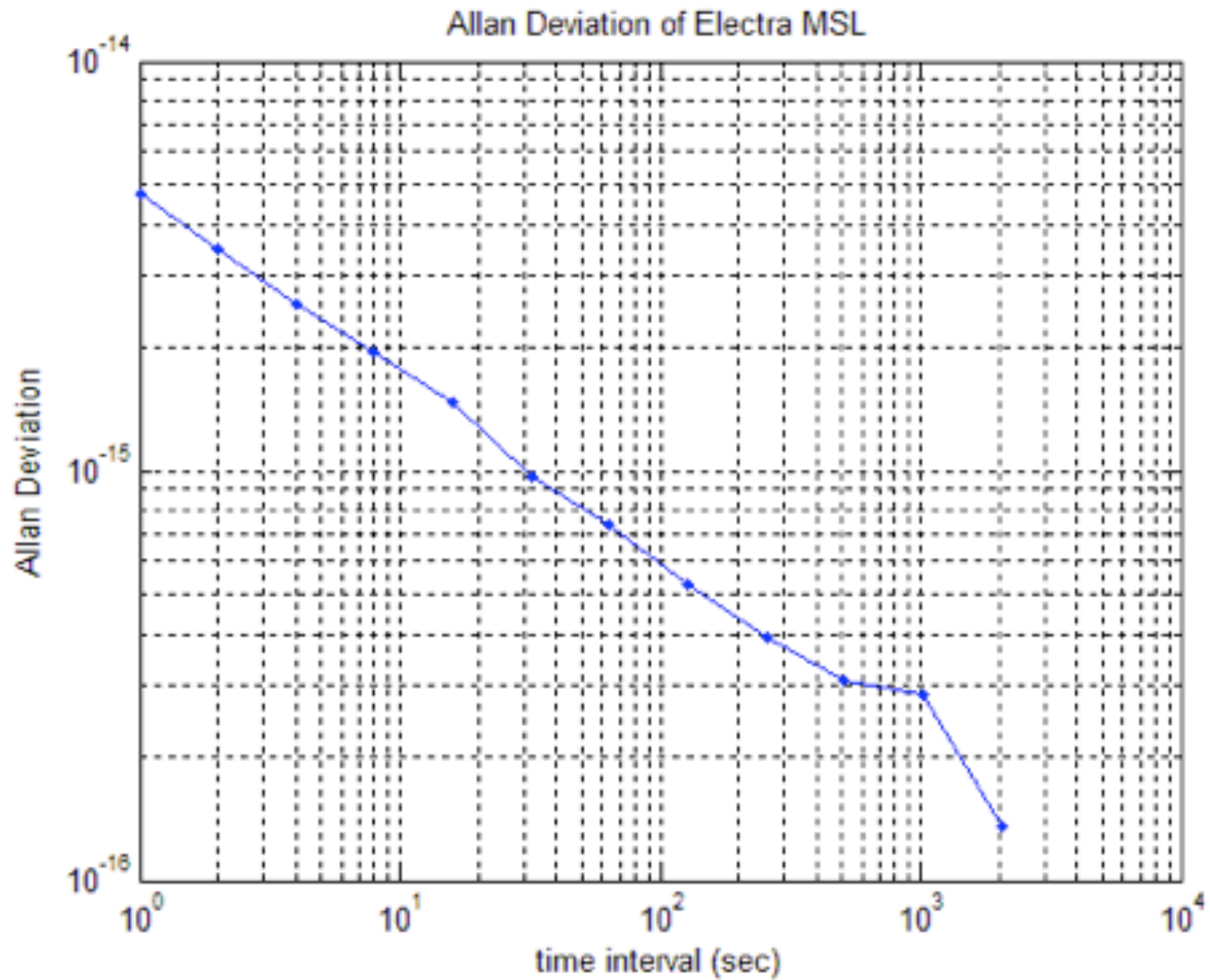


RASSI: Radio Atmospheric Sounding & Surface Scattering Instrument

- Software Radio Receiver based on Electra Payload
- Science quality oscillator, ADC, filters, etc.
- Front-end down-converters (depends on optimum wavelength)
- Advantages of Open-Loop Reception
- Mass & power tradeoffs
- Surface scattering optimum configuration
- Digital design meets Radio Science specifications



Allan Deviation (Phase Stability)



Summary

- Investigations of planetary atmospheres and surfaces via radio occultation and scattering techniques conducted on many planets and satellites via *one-way downlink* from a spacecraft to a ground station
- Limitations on the received SNR or geometrical coverage can be overcome with alternate observation configurations
- *Uplink observations* can have SNR advantage ~ 3 orders of magnitude
- *Spacecraft-to-spacecraft observations* have significant SNR advantage and can yield improved geometrical coverage
- A special radio science receiver is required onboard the spacecraft
- New digital open-loop receiver designed to meet the Radio Science requirements
- Ready for future missions!

Acknowledgement

The described work was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.